night. The largest of these fishes, which were all of the same species, were nine to ten inches in length, and having been taken immediately from the beak of the bird were scarcely bruised. The largest and best of these we had the next morning for breakfast, the others we gave to our friend, the cormorant, who was kindly assisted by his master to get them past the cord which constricted his throat so that he could not otherwise have swallowed.

The birds are trained especially for the work, and do not fish in the day-time. Our bird was two years old, and was considered a very bright and active fisher, having on good nights, fishing all night, caught as many as 400 fishes,—300 was considered a fair night's work. Only calm nights are available, and the darker the better.

THE MECHANICAL CAUSES OF THE ORIGIN OF THE DENTITION OF THE RODENTIA.

BY E. D. COPE.

THE phylogeny of the Rodentia as an order is now tolerably clear. I at first suggested,[1] and later asserted, that this order was derived by descent from the Tillodont suborder of the Bunotheria. The Tillodont suborder had a common origin with the Tæniodonta, from some type of Bunotheria with unspecialized molars and premolars, in which some of the incisor teeth had begun to display enlarged size. A form allied to this ancestor is the genus Esthonyx, which differs from it in but few respects. Professor Ryder, in discussing the origin of the Rodentia,[2] writes as follows:

"The significance of accessory rudimentary incisors present in some forms of true rodents, as pointing to the manner in which the evolution of the rodent type of dentition took place, may be overrated; yet when it is borne in mind that in other groups the appearance of diastemata between the different kinds of teeth took place gradually and in a way which unmistakably shows the gradual steps of the

[1] American Naturalist, April, 1883; Report U. S. Geol. Surv. Tertiary Vertebrata, 1885, 814; American Naturalist, April, 1884.

[2] Proceed. Academy Philada., 1877, p. 317.

process, we may be excused for thinking the same to have been the case here, although without positive tangible evidence in the shape of intermediate fossil forms that exhibit such a passage from the ordinary type." In 1852 I had the pleasure of discovering a genus [1] (Psittacotherium Cope) which supplies the desideratum wanting when Professor Ryder wrote. This is a genus, without diastema, and with two effective rodent-like incisors in each ramus of the lower jaw. Ectoganus Cope is probably similar in these respects, but only its separate teeth have been found. Psittacotherium is, then, a generalized type, and is not far from, if not directly in, the line of the ancestry of all Rodentia. It belongs to the Puerco fauna, which embraced so many of the progenitors of later Mammalia (Fig. 1).

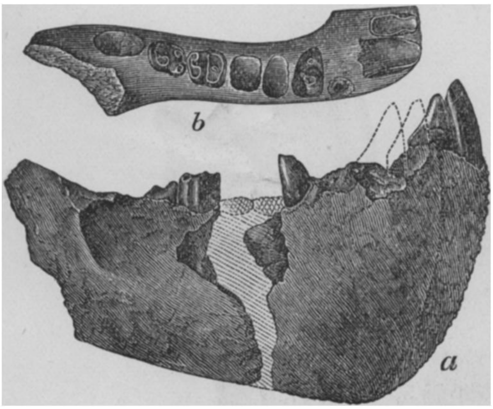

FIG. 1. *Psittacotherium multifragum* Cope, left mandibular ramus, one-half natural size. Original; from Puerco bed of New Mexico. Fig. *a*, external view; *b*, superior view.

I have called attention to the fact that the first inferior incisor is rudimental in Calamodon, and Marsh has shown the same thing in Tillotherium. In both genera the second incisor is the effective tooth. The third is present in Calamodon (Fig. 2). In Tillotherium the third incisor is apparently wanting. In Psittacotherium the first incisor tooth is present and effective, but the second is larger. It is not certain whether these are first and second, or second and third incisors. If we allow Esthonyx to decide the question, the large second tooth is truly the second incisor, for in that genus the first incisor is small, and the third is rudimental. With present information, then, the inferior incisor of the Rodentia is the second of the Mammalian series.[2]

[1] American Naturalist, Feb., Tertiary Vertebrata, 1885, p. 195.

[2] I have regarded (Naturalist, 1884, April and earlier) the Tæniodonta as the ancestors of the Edentata. The objection to this view is the supposed absence of inferior incisors in the latter. But the middle incisors

The peculiarities of the rodent dentition consist, as is well known, in the great development of the incisors; the loss of all but one, or rarely of two, of the premolars, which leaves a wide diastema; and the posterior position of the molar teeth, as relates to the rest of the skull. A peculiarity which belongs to the highest types of the order is the prismatic form of the molars, and the deep inflection of their always transverse enamel folds, both laterally and vertically. A peculiarity of the masticating apparatus, which is the basis of distinction from the Bunotherian order, is the lack of postglenoid process, and the consequent freedom of the lower jaw

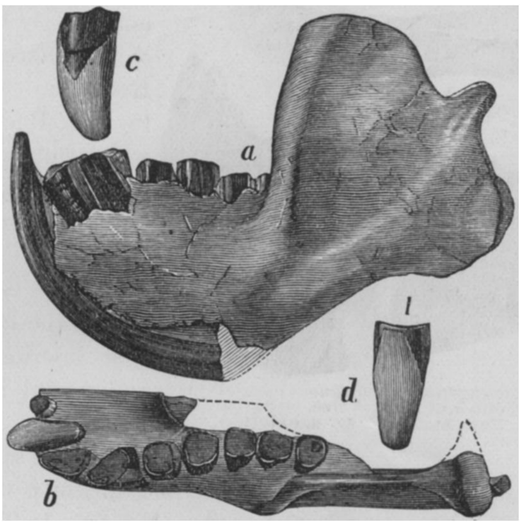

FIG. 2. *Calamodon simplex* Cope, lower jaw, left ramus, one-third natural size. Original, from Wasatch Eocene, of Wyoming. Fig. *a*, external view; *b*, superior, *c-d*, inferior molar; *c*, exterior; *d*, posterior views.

to slide backward and forward in mastication. Appropriately to this motion the condyle of the mandible is either subglobular, or is extended anteroposteriorly, and the glenoid cavity is a longitudinal instead of a transverse groove.

The mechanical action of the development of the rodent dentition has been as follows: The first factor in the order of time and importance was the increasing length of the incisor teeth.

are disappearing from the Tæniodonta, while the supposed canines of the lower jaw of Megalonyx and allies may be true incisors. This is rendered probable by the genus Diadomus of Ameghino, where the large canine-like teeth are found close together at the symphysis mandibuli, like the incisors of Tæniodonta and Rodentia.

Those of the lower jaw closed behind those of the upper in the progenitors of the Rodentia (*e.g.*, Esthonyx), as in other Mammalia. Increase of length of these teeth in both jaws would tend to keep the mouth permanently open, were it not for the possibility of slipping the lower jaw backwards as it closed on the upper. This backward pressure has undoubtedly existed, and has operated from the earliest beginning of the growth of the rodent incisors. The process has been precisely the opposite of that which has occurred in the Carnivora, where the pressure has been ever forwards, owing to the development of the canines.[1] The

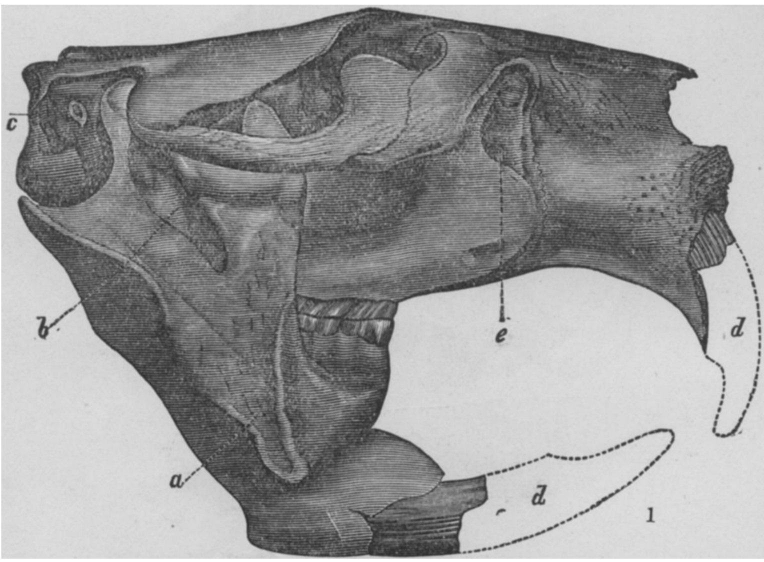

FIG. 3. *Castoroïdes ohioensis* Foster, skull, right side, two-fifths natural size. Fig. *a*, inferior insertion of masseter muscle; *b*, fossa in side of ascending ramus; *c*, external auditory meatus; *d*, incisors; *e*, foramen infraorbitale. From Hall & Wyman.

progressive lengthening of the incisors through use has been dwelt on by Professor Ryder (l. c.). The posterior pressure on the lower jaw, produced by its closing on the upper, has been increased directly as the increase of the anteroposterior length of the incisors, especially those of the lower jaw.

The first effect of this posterior pressure will have been to slide the condyle of the mandible posteriorly over the postglenoid process, if any were present, as is probable, in the bunotherian ancestor of the rodent. Continued repetition of the movement would probably push the process backwards, so as to render it ineffective as

[1] Proceed. Amer. Assoc. Science, 1887.

a line of resistance, and ultimately to flatten it out, and atrophy it. The lower jaw would thus come to occupy that peculiarly posterior position which it does in all rodents.

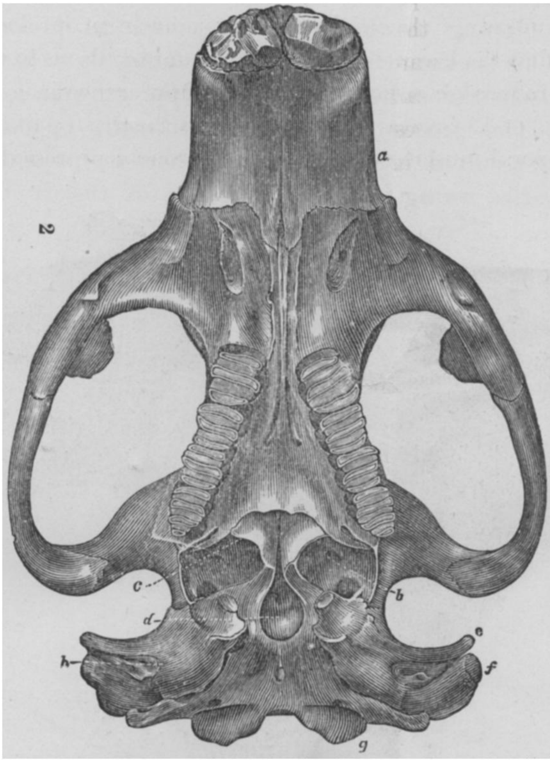

FIG. 4. *Castoroïdes ohioensis* Foster, two-fifths natural size, skull from below. Fig. *a*, incisive foramen; *b*, pterygoid fossa; *c*, internal pterygoid plates; *d*, fossa in basioccipital bone; *e*, external auditory meatus; *f*, mastoid process; *g*, occipital condyles; *h*, tympanic bulla; after Hall and Wyman.

The anteroposterior (propalinal)[2] type of mastication becoming necessary, an appropriate development of the muscles moving the lower jaw, with their insertions, follows *pari passu*. As a result we see that the insertion of the temporal muscle creeps forwards on the ramus, until in the highest rodents (Cavia) it extends along the ramus to opposite the first true molars. The office of this mus-

[2] See Naturalist, Nov., 1887, p. 991, for explanation of the different modes of mastication. The propolinal mastication is to be distinguished into the proal, from behind forwards (the Proboscidea, Ryder), and the palinal from before backwards (the Rodentia, Ryder).

cle is to draw the ramus backwards and upwards, a movement which is commenced so soon as the inferior incisor strikes the apex of the superior incisor on the posterior side. By this muscle the inferior molars are drawn posteriorly and in close opposition to the superior molars. Connected with this movement, probably as an effect, we find the coronoid process of the mandible to have become gradually reduced in size, to complete disappearance in some of the genera, *e.g.*, of Leporidæ. In these genera the groove-like insertion of the temporal muscle develops as the coronoid process disappears.

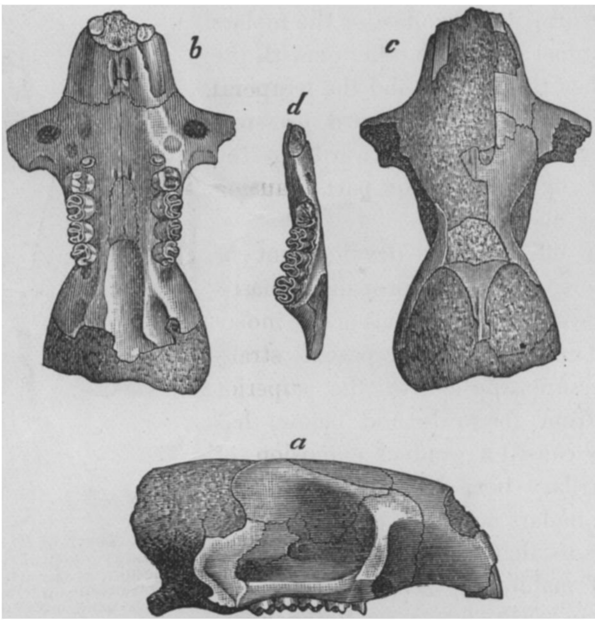

FIG. 5. *Ischyromys typus* Leidy, natural size, from the White river beds of Colorado; original, from the Report U. S. Geol. Surv. Terrs. *a*, *b*, *c*, cranium; *d*, mandible from above.

As third and fourth effects of the posterior position of the lower jaw, we have the development of the internal pterygoid and masseter muscles and their insertions and origins. The angle of the ramus being forced backwards, these muscles are gradually stretched backwards at their insertions, and their contraction becomes more antero-posterior in direction than before. The internal pterygoid becomese specially developed, and its point of origin, the pterygoid fossa, becomes much enlarged. The border of the angle of the mandible becomes more or less inflected. In their effect on the move-

ments of the ramus they oppose that of the temporal muscle, since they draw the ramus forwards. They are the effective muscles in the use of the incisor teeth, that is, in the opposition of the inferior incisors against the superior, from below and posteriorly. Hence the great development of the internal pterygoid, and, in a less degree, of the masseter. Both muscles tend also to close the jaws, but at a different point in the act of mastication from that at which the temporal acts. If we suppose the mouth to be open, the action of the masseter and internal pterygoid muscles draws the mandible forward and upwards until the incisors have performed their office, or the molars are in contact with each other or with the food. They then relax, and the temporal muscle continues the upward pressure, but draws the ramus backwards to the limit set by the adjacent parts, causing the act of mastication.

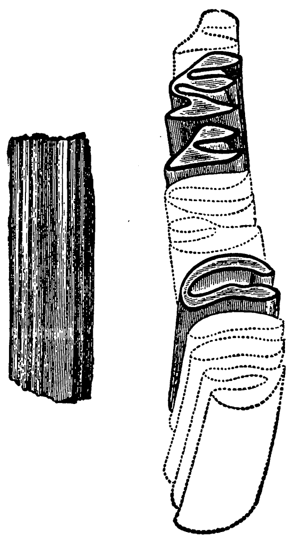

FIG. 6. Teeth of *Hydrochœrus æsopi* Leidy, natural size. From Charleston, S. C. After Leidy. *a*, fragment of superior incisor; *b*, the shaded portions represent parts of inferior molars found.

A fifth effect of the development of the incisors, and of the propalinal mastication, is seen in the positions of the molar teeth. The indefinitely repeated strain and pressure applied to the superior molars from forwards and below, has evidently caused a gradual extension of the maxillary bone backwards, so that the last molars occupy a position much posterior to that which they do in other orders of mammals. This is especially the case in such forms as Bathyergus, Arvicola and Castoroïdes (Fig. 4), where the last molars are below the temporal fossa, and posterior to the orbit.

A sixth effect of the causes mentioned has been referred to by Ryder.[1] This is the oblique direction of the axes of the molar teeth. These directions are opposite in the two jaws; upwards and forward for the lower, and downward and backwards for the upper. The mechanics of this change of direction from vertical in the primitive forms (Sciuridæ) to oblique in the genera with prismatic molars, is simple enough. The inferior crowns, when

[1] Proceed. Acad. Philada., p. 66, Figs. 8, b and f.

closely appressed to the superior, and drawn posteriorly in the direction of the long axis of the jaw, press and strain the teeth in the two directions mentioned. The development of the long prismatic crowns which has proceeded under these circumstances, has been undoubtedly affected by the pressure and strain, and the direction we find has been the result.

The seventh effect is in the detailed structure of the teeth themselves. Beginning with short crowns with simple transverse crests, (Psittacotherium and Sciuridæ, Figs. 1 and 5), we reach, through intermediate forms, crowns with vertical laminæ of enamel, which sometimes divide the crown entirely across (Chinchillidæ, Caviidæ, Castoroididæ), or appear only on the ends of the crown, through the continued coalescence of the prisms of which each molar crown is composed (Arvicola). In many instances the crowns increase in transverse at the expense of their longitudinal diameter (Castor, Lepus). The vertically laminated structure is evidently due to the crowding together of transverse crests by the same pressure which has given the crowns their oblique direction. In many genera the lengthening of the crown has included the lengthening of the longitudinal connection between the transverse crests, as in Arvicola, Castor and Hystricidæ generally. In others this connection has not been continued, so that the crown is composed of prisms which are separate to near the base, as in Amblyrhiza and Saccomyidæ. In others, connection between the prisms has been lost by cœnogeny, as in Chinchillidæ and Caviidæ generally. The latter families display also the greatest amount of crowding (Fig. 6).

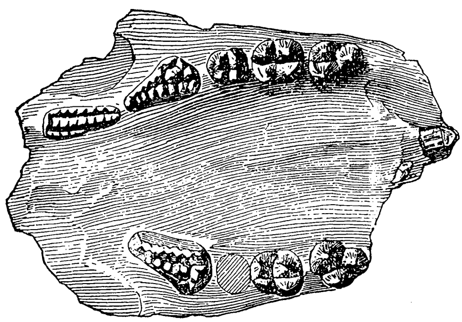

FIG. 7. *Chirox plicatus* Cope, palate and molar teeth from below, three-halves natural size. From Puerco bed of New Mexico. From American Naturalist, 1887, p. 566.

A peculiarity of the plication of rodent molars I am unable to explain as yet on mechanical principles. In genera which are isognathous, the inflections are of equal depth on opposite sides of both superior and inferior molars. In anisognathous genera

the inflections are more numerous and profound on opposite sides of the molars of the respective jaws. Anisognathism in rodents is generally, as shown by Ryder, of the type where the inferior molars include a wider expanse than the superior, though this

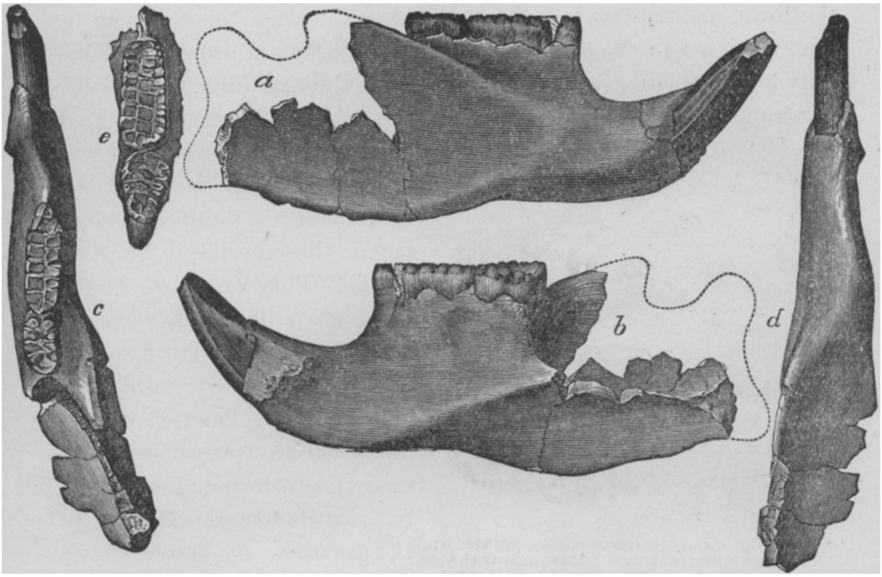

FIG. 8. *Polymastodon taöensis* Cope, jaws, two-thirds natural size, from Puerco bed of New Mexico. Figs. *a-d*, lower jaw; *e*, upper jaw. Original.

applies in some instances more to the direction of the roots rather than the position of the crowns. In Lepus the lower jaw is the narrower. The two types of anisognathism may be termed hypanisognathism (Lepus, Diplarthra) and epanisognathism (Caviidæ). The following genera display these characters:—

Hypanisognathous.	*Isognathous.*	*Epanisognathous.*
Lepus.	Arvicola.	Hystricidæ.
	Capromys.	Castor.
		Caviidæ.

In conclusion I will say that it is satisfactorily proven to my mind that nearly all of the peculiarities of the Rodent dental system, and manner of mastication, are the mechanical consequences of an increase in the length of the incisor teeth. And the increase in the length of these teeth has been due to their continued use, as believed by Ryder.

Note on the Marsupialia Multituberculata.—The structure of the dentition of this suborder is in many respects like that of the Rodentia in the known forms. The incisors in the Plagiaulacidæ, Chirogidæ and Polymastodontidæ have structure and functions generally similar to those of the Rodentia. The result in the form and function of the molar dentition has been similar to that observed in the Rodentia. The postglenoid process is probably absent in these animals; in any case the mandible, or condyle, is rounded and is not transverse. Professor H. F. Osborn has pointed out to me that mastication was performed by a fore and aft movement of the inferior molars on the superior, in Plagiaulacidæ. This was no doubt the case in the other families named. The resulting structure of the crowns is, however, different, and needs explanation. The molar teeth present conical tubercles in longitudinal series, two in the lower, and three in the upper jaw. The two series of the lower jaw alternate with the three in the upper jaw, moving in the grooves between the latter, while the three series of the upper molars reciprocally embrace the two of the lower molars. This is demonstrated by the mutual wear of the tubercles seen in Ptilodus and Chirox (Fig. 7). The trituration was probably the same in Tritylodon, but in Polymastodon the increased thickening of the tubercles prevented their interlocking action in mastication. In this genus the tubercles slid over each other, and truncated the apices until in old specimens they were entirely worn away (Fig. 8 *c e*). In Meniscoëssus and Stereognathus we have an interesting illustration of the effect of the action of cusps on each other when under prolonged mutual lateral thrust. Their external sides have been drawn out into long angles in the direction of thrust, converting their transverse sections from circles to crescents. As the thrust is in the longitudinal Multituberculata, the crescents are

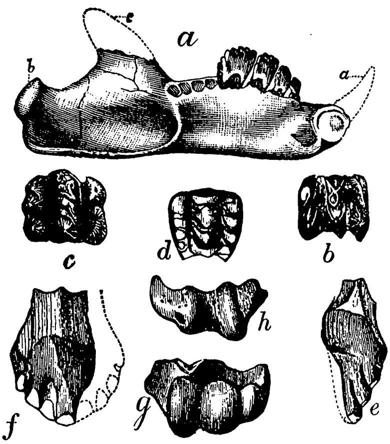

Fig. 9. Marsupialia Multituberculata. Fig. *a*, *Ctenacodon serratus* Marsh, $\frac{3}{1}$ from Marsh; *d*, *Meniscoëssus conquistus* Cope three-halves natural size; *b*, superior molar' *g e*, humeral condyles; *f h*, premolar. Fig' *d*, *Stereognathus oöliticus* Owen $\frac{3}{1}$, from Owen: c, *Tritylodon longaevus* Owen $\frac{3}{1}$, from Owen. ;

PLATE I.

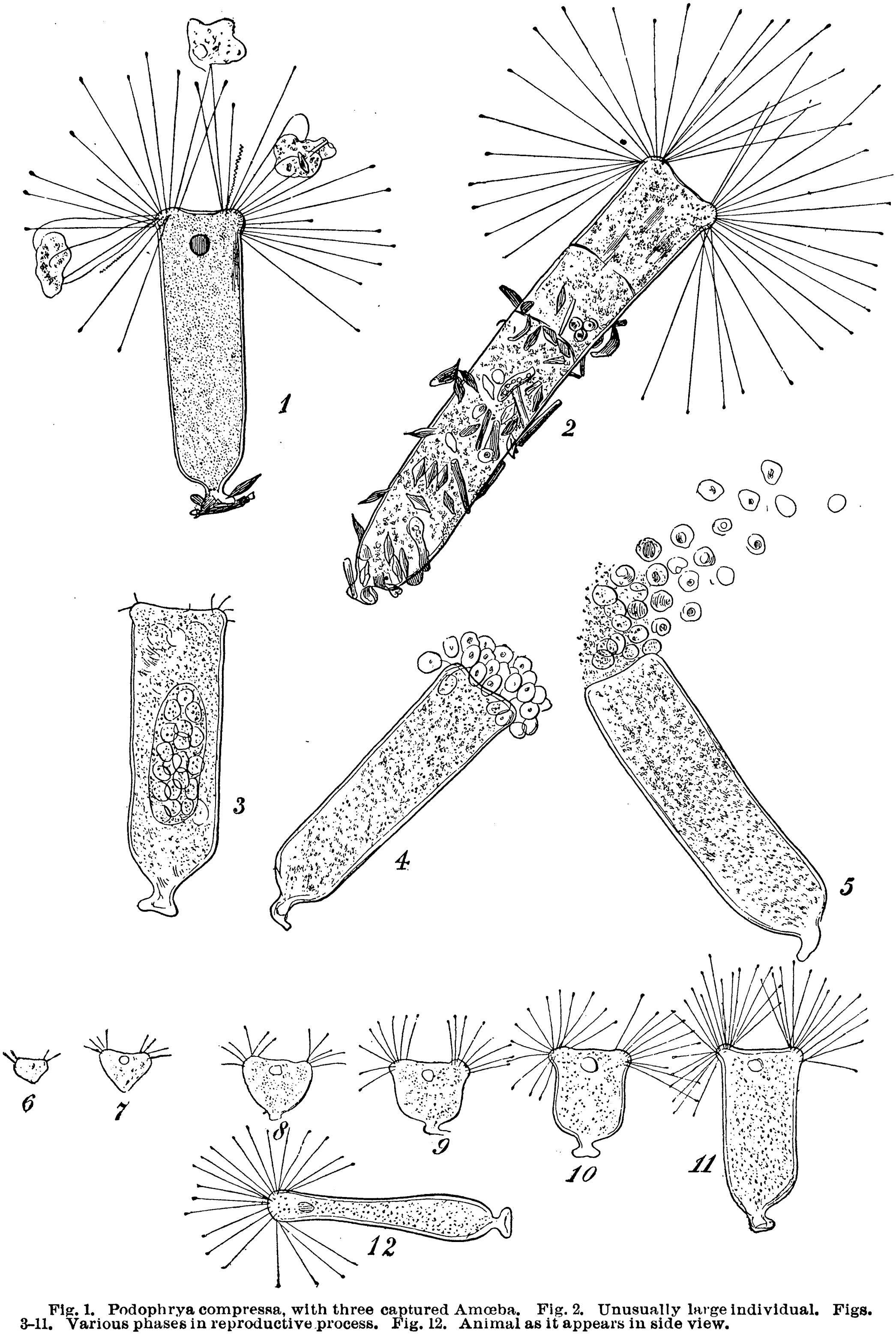

Fig. 1. Podophrya compressa, with three captured Amœba. Fig. 2. Unusually large individual. Figs. 3-11. Various phases in reproductive process. Fig. 12. Animal as it appears in side view.

transverse to the axis of the jaw. In the selenodont Diplarthra, where the thrust is transverse to the line of the jaw, the crescents are longitudinal. That similar effects should accompany similar movements in two groups of Mammalia so widely separated as these two, is strong evidence in favor of the belief that the two facts stand in the relation of cause and effect (Fig. 9, Figs. *b* and *d*).

DESCRIPTION OF A SUPPOSED NEW SPECIES OF ACINETAN, WITH OBSERVATIONS ON ITS MANNER OF FOOD INGESTION AND REPRODUCTION.

BY C. C. NUTTING.

PODOPHRYA COMPRESSA Nutting.

DESCRIPTION:—Body illoricate, quadrate, wider anteriorly; length from two to five times the greatest width; compressed, about three times as wide as thick; the anterolateral corners occupied by rounded prominences, each bearing a fascicle of many suctorial tentacles which, when fully extended, are more than half the length of the body, and spiral or spirally marked when retracted; posterior portion of body rapidly narrowing to meet the very short thick pedicle which is furnished with a sucking disk at its distal end; parenchyma densely and evenly granular; contractile vacuole single, anterior; endoplast oval.

Length of body, 1–277″ to 1–140″.

Habitat. Fresh water.

The above-described species has recently been numerous in a fresh-water aquarium in the Biological Laboratory of the State University of Iowa, where it was first noticed by Professor S. Calvin, who kindly delegated its investigation and description to the writer.

In general appearance it somewhat resembles certain species of the genus *Acineta*, but the absence of any indication of a lorica excludes it from that group, and it is hence, with some doubt, placed in the genus *Podophrya*, with which it agrees in possessing distinctly capitate, fasciculated, suctorial tentacles only. It is